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PROGRESS REPORT

Properties Occurrence and Management of Soils with Vesicular Surface Horizons

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Between

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Nevada Agricultural Experiment Station

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INTRODUCTION

Forested watersheds in the western United States produce most of the streamflow whereas rangeland-watersheds produce most of the sediment load. High intensity, short duration summer thunderstorms account for most of the runoff and sediment from arid and semiarid rangelands. The amount of runoff and sedimentation is conditioned by the amount of vegetative cover and by the proportion of coppice dune and dune interspace soils.

A coppice dune is an area of accumulation of litter and soil under trees, shrubs, and bunchgrasses of desert areas. Dune interspace is the area between coppice dunes. Vesicular soil surface horizons are found extensively on Aridisols in the dune interspace position. Vesicular horizons are a major factor contributing to low infiltration rates and sediment production.

The purposes of the study are: 1) describe the characteristics of different types of soil surfaces in Aridisols, 2) evaluate methods to increase vegetative cover and the amount of coppice dune through revegetation techniques, and 3) determine the effects of ORV traffic on infiltration and sediment production characteristics of soils with vesicular surface horizons. This report presents the results of this study for 1975.

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SITE DESCRIPTION

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Four 0.5 hectare seeding exclosures were established in northern Nevada

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Four 0.5 hectare seeding exclosures were established in northern Nevada

in fall, 1974. These were located as follows: two sites at Coils Creek about 32 airline miles northwest of Eureka; one site at Panther Canyon about 35 miles south of Winnemucca; and one site in Paradise Valley about 40 miles north of Winnemucca. All sites are located in the big sagebrush (Artemisia tridentata) type.

Precipitation

Precipitation between mid October, 1974 and mid May 1975 were as follows: Lower Coils Creek, 18.0 cm; Upper Coils Creek, 22.1 cm; Panther Canyon, 24.1 cm; and Paradise Valley, 17.3 cm.

Extent of Coppice and Interspace Soil Type - Percent Surface Cover

There was significantly less coppice dune cover than dune interspace cover at all sites (Table 1). There was no significant difference in coppice dune cover among Lower Coils Creek, Upper Coils Creek, and Panther Canyon. The same relationship existed for dune interspace cover. The coppice dune cover at Paradise Valley was significantly lower than the other three sites. The dune interspace cover at Paradise Valley was significantly higher than the other three sites.

Vegetation

Shrub cover was highest at Upper Coils Creek but not significantly different from Lower Coils Creek or Panther Canyon (Table 2). Shrubs at Upper Coils Creek were big sagebrush (23.9%), low sagebrush (Artemisia arbuscula) (1.7%), and Yellow brush (Chrysothamnus viscidiflorus) (0.2%). Shrubs at Lower Coils Creek were big sagebrush (22.2%) and low sagebrush (1.4%). Shrubs at Panther Canyon were big sagebrush (19.3%) and spiny hopsage (Grayia spinosa) (1.1%). Shrub cover was lower at Paradise Valley but not significantly different from Panther Canyon. Shrubs at Paradise Valley were big sagebrush (15.5%) and

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Precipitation

Precipitation between end October, 1978 and end May 1979 were as follows: Lower Colls Creek, 18.0 cm; Upper Colls Creek, 21.1 cm; Panther Canyon, 24.1 cm; and Paradise Valley, 17.3 cm.

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Vegetation

Shrub cover was highest at Upper Colls Creek but not significantly different from Lower Colls Creek or Panther Canyon (Table 2). Shrubs at Upper Colls Creek were big sagebrush (13.9%), low sagebrush (Artemisia arbuscula) (1.7%), and Yellow brush (Chrysothamnus viscidiflorus) (0.2%). Shrubs at Lower Colls Creek were big sagebrush (15.2%) and low sagebrush (1.9%). Shrubs at Panther Canyon were big sagebrush (14.3%) and spiny hopsage (Grayia spinosa) (1.5%). Shrub cover was lower at Paradise Valley but not significantly different from Panther Canyon. Shrubs at Paradise Valley were big sagebrush (12.9%) and

Table 1. Mean percent soil surface cover of coppice dune and dune interspace soils at the four study sites.[1/]

	Percent	
	Coppice dune	Dune interspace
Lower Coils Creek	43.2 b	56.8 a
Upper Coils Creek	38.5 b	61.5 a
Panther Canyon	38.2 b	61.8 a
Paradise Valley	15.6	84.4

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 2. Mean percent foliage cover of shrubs at the four study sites.[1/]

	Percent
Lower Coils Creek	23.48 ab
Upper Coils Creek	23.92 a
Panther Canyon	20.4 ab
Paradise Valley	15.5 b

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

horsebrush (Tetradymia canescens) (0.2%).

Perennial grass cover (Table 3) was greatest at Panther Canyon. Grasses were Sandberg bluegrass (Poa sandbergii) (6.7%), squirreltail (Sitanion hystrix) (1.8%), and Great Basin Wildrye (Elymus cinereus) (0.7%). Second highest cover was at Upper Coils Creek and it was significantly higher than at Paradise Valley and Lower Coils Creek. Perennial grasses at Upper Coils Creek were Thurber needlegrass (Stipa thurberiana) (1.6%), Sandberg bluegrass (1.5%), and squirreltail (0.7%). Perennial grasses at Paradise Valley were crested wheatgrass (Agropyron desertorum) (0.7%), squirreltail (0.5%), and Sandberg bluegrass (0.4%). Perennial grasses at Lower Coils Creek were Sandberg bluegrass (1.1%) and squirreltail (.02%).

Annual plants (Table 4) at Panther Canyon included cheatgrass (Bromus tectorum) (4.4%). Second highest cover was at Paradise Valley and it was not significantly different from either Coils Creek site. The annual plants were tumble mustard (Sisymbrium altissimum) (0.5%) and cheatgrass (1.3%).

METHODS

Revegetation

A portion of each exclosure area was divided into forty 20x20 ft. subplots. Twenty subplots were deep plowed and 20 were not plowed. In both treatments four seeding techniques were used in fall, 1974: 1) drill to simulate a standard rangeland drill, 2) drill to simulate a deep-furrow rangeland drill, 3) broadcast with simulated cow trampling, 4) broadcast without simulated cow trampling. Four species were seeded: 1) squirreltail, 2) Thurber needlegrass, 3) crested wheatgrass, and 4) fourwing saltbush. Seeding rate was 2 seeds/inch of row in drill rows and 20 seeds/ft^2 in the broadcast treatments. Ten fourwing saltbush seeds/ft^2 were seeded in the broadcast treatments. Each treatment was replicated five times. Seedling counts were made in the spring

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Table 3. Mean percent basal area cover of perennial grasses at the four study sites.[1/]

	Percent
Lower Coils Creek	1.14 a
Upper Coils Creek	3.76
Panther Canyon	9.21
Paradise Valley	1.52 a

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

Table 4. Mean percent basal area cover of annual plants at the four study sites.[1/]

	Percent
Lower Coils Creek	0 a
Upper Coils Creek	0 a
Panther Canyon	4.36
Paradise Valley	1.82 a

1/ Means followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's Multiple Range Test.

and summer of 1975 on coppice and interspace soils and converted to percent emergence based on number of seeds planted.

RESULTS AND DISCUSSION

Seedling Emergence in Plowed and Unplowed Soils

At Lower Coils Creek (Table 5), seedling emergence in unplowed and plowed was similar. Deep-furrow drill treatment gave the highest emergence for all species. Standard drill was second highest but was not significantly different from the deep-furrow drill treatment. Broadcast-simulated cow trampling was third highest and was significantly lower than the standard drill treatment. The broadcast - no simulated cow trampling treatment virtually failed but was not significantly different from broadcast-simulated cow trampling.

At the Upper Coils Creek site (Table 6) emergence was not significantly different on unplowed and plowed soil. The deep-furrow drill treatment resulted in highest emergence for all species except for Thurber needlegrass in the unplowed soil. Second highest emergence was by the broadcast-simulated cow trampling but it was not significantly lower than deep-furrow drill nor higher than the standard-drill treatment. Broadcast-no simulated cow trampling was significantly lower than all other treatments.

At Panther Canyon (Table 7) emergence in unplowed and plowed soils was similar. Highest emergence was on the broadcast-simulated cow trampling treatment. Deep-furrow drill was second highest but was not significantly lower than the broadcast-simulated cow trampling treatment nor significantly higher than the standard drill. Emergence in the standard-drill treatment was significantly lower than in the broadcast-simulated cow trampling but was not significantly lower than the deep-furrow drill treatment. The broadcast-no simulated cow trampling treatment gave the poorest results.

At Paradise Valley (Table 8) emergence was significantly higher

Table 5. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune-interspace soil under the various treatments in the Lower Coils Creek study plot.

Treatment	% Emergence[1/] Coppice	% Emergence[1/] Interspace	Treatment	% Emergence[1/] Coppice	% Emergence[1/] Interspace
Soil	10.2	3.5			
Soil x species			Soil x species x seeding method		
Crested wheatgrass	14.3a	5.8bc	Standard drill	21.6b	10.8de
			Deep-furrow drill	30.8a	8.4def
			Broadcast-simulated cow trampling	4.4efg	3.9fg
			Broadcast-no simulated cow trampling	0.3g	0.2g
Squirreltail	10.5ab	3.1bc	Standard drill	16.5bc	6.0efg
			Deep furrow drill	21.6b	4.8efg
			Broadcast-simulated cow trampling	3.1 fg	1.3g
			Broadcast-no simulated cow trampling	0.5g	0.5g
Thurber needlegrass	6.0bc	1.5c	Standard drill	10.8de	2.7fg
			Deep-furrow drill	13.2cd	3.0fg
			Broadcast-simulated cow trampling	0.0g	0.0g
			Broadcast-no simulated cow trampling	0.0g	0.3g

1/ Emergence means within soils, soils x species, or soils x species x seeding method followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple-range test.

Table 6. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune-interspace soil under the various treatments in the Upper Coils Creek study plot.

Treatment	% Emergence[1/]		Treatment	% Emergence[1/]	
	Coppice	Interspace		Coppice	Interspace
Soil	20.6	10.7			
Soil x species			Soil x species x seeding method		
Crested wheatgrass	22.5a	11.5b	Standard drill	26.3 abcde	14.5defgh
			Deep-furrow drill	40.5a	16.7defgh
			Broadcast-simulated cow trampling	19.0edefg	11.5efgh
			Broadcast-no simulated cow trampling	4.1gh	3.4gh
Squirreltail	25.1a	9.8b	Standard drill	23.6bcdef	7.3fgh
			Deep-furrow drill	38.6ab	14.7defgh
			Broadcast-simulated cow trampling	30.4 abcd	14.2defgh
			Broadcast-no simulated cow trampling	7.8fgh	2.8gh
Thurber needlegrass	14.4b	10.9b	Standard drill	16.6defgh	3.1gh
			Deep-furrow drill	16.5defgh	5.7gh
			Broadcast-simulated cow trampling	18.7cdefg	33.6abc
			Broadcast-no simulated cow trampling	5.8gh	1.1h

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Table 7. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune-interspace soil under the various treatments in the Panther Canyon study plot.

Treatment	% Emergence[1/] Coppice	% Emergence[1/] Interspace	Treatment	% Emergence[1/] Coppice	% Emergence[1/] Interspace
Soil	11.1	3.3			
Soil x species			Soil x species x seeding method		
Crested wheatgrass	15.6a	3.0bc	Standard drill	14.3bcde	0[2/] f
			Deep-furrow drill	24.7a	5.7ef
			Broadcast-simulated cow trampling	21.5ab	6.0def
			Broadcast-no simulated cow trampling	2.0f	0.3f
Squirreltail	11.1ab	5.0bc	Standard drill	8.9cdef	0[2/] f
			Deep-furrow drill	16.0abcd	8.0cdef
			Broadcast-simulated cow trampling	16.5abc	10.0cdef
			Broadcast-no simulated cow trampling	3.0f	2.0f
Thurber needlegrass	6.6abc	1.8c	Standard drill	5.2ef	0[2/]
			Deep-furrow drill	5.4ef	0.6f
			Broadcast-simulated cow trampling	13.3bcde	6.7def
			Broadcast-no simulated cow trampling	2.3f	0[2/] f

1/ Emergence means within soils, soils x species, or soils x species x seeding method followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple-range test.

2/ No interspace was present.

Table 8. Mean percent emergence of crested wheatgrass, squirreltail, and Thurber needlegrass in coppice dune and dune-interspace soil under the various treatments in the Paradise Valley Study plot.

Treatment	% Emergence[1/] Coppice	% Emergence[1/] Interspace	Treatment	% Emergence[1/] Coppice	% Emergence[1/] Interspace
Soil	16.4	8.5			
Soil x species			Soil x species x seeding method		
Crested wheatgrass	22.7a	11.7b	Standard drill	32.4ab	33.7ab
			Deep-furrow drill	41.4a	8.7cd
			Broadcast-simulated cow trampling	14.7c	3.8cd
			Broadcast-no simulated cow trampling	2.3d	.4d
Squirreltail	21.4a	11.6b	Standard drill	40.0ab	29.3b
			Deep-furrow drill	35.6ab	10.6cd
			Broadcast-simulated cow trampling	8.0cd	4.8cd
			Broadcast-no simulated cow trampling	2.2d	1.8d
Thurber needlegrass	5.0c	1.2c	Standard drill	3.7cd	1.8d
			Deep-furrow drill	5.8cd	2.5d
			Broadcast-simulated cow trampling	9.3cd	.5d
			Broadcast-no simulated cow trampling	1.2d	.2d

1/ Emergence means within soils, soils x species, or soils x species x seeding method followed by the same letter are not significantly different (0.05) as determined by Duncan's multiple-range test.

in the unplowed soil than in the plowed soil. The standard drill technique gave the greatest percent emergence followed by the deep-furrow drill. Broadcast-simulated cow trampling was third. Broadcast-no simulated cow trampling was lowest in emergence and this treatment completely failed.

Seedling Emergence In Coppice and Interspace

At Lower Coils Creek, significantly more seedlings emerged in the coppice than in the interspace soil (Table 5). Emergence of crested wheatgrass was higher than squirreltail, and squirreltail was higher than Thurber needlegrass in both coppice and interspace. In the coppice soil, emergence of crested wheatgrass and squirreltail was not significantly different nor were squirreltail and Thurber needlegrass. A significant difference did exist between crested wheatgrass and Thurber needlegrass. In the interspace soil, emergence of all species was similar.

Under the various seeding treatments, crested wheatgrass in deep-furrows in coppice soil had the highest emergence. Highest emergence of all species was in deep-furrows but this treatment was not significantly better than the standard drill except with crested wheatgrass in the coppice soil. Emergence in the broadcast-simulated cow trampling treatment was significantly lower than either drill treatment but not significantly higher than the broadcast-no simulated cow trampling treatment. The latter treatment failed or nearly failed for all species in both soils.

At Upper Coils Creek, significantly more seedlings emerged in the coppice than in the interspace soil (Table 6). Emergence of crested wheatgrass was lower than squirreltail in the coppice soil and higher than squirreltail in the interspace, although not significantly. Emergence of both these species was significantly higher than Thurber needlegrass in the coppice soil. Thurber needlegrass emergence was higher in the interspace than squirreltail but lower than crested wheatgrass.

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At Lower Colly Creek, significantly more seedlings emerged in the coppice than in the interspace soil (Table 5). Emergence of crested wheatgrass was higher than squirreltail, and squirreltail was higher than Thurber needlegrass in both coppice and interspace. In the coppice soil, emergence of crested wheatgrass and squirreltail was not significantly different nor were squirreltail and Thurber needlegrass. A significant difference did exist between crested wheatgrass and Thurber needlegrass. In the interspace soil, emergence of all species was similar.

Under the various seeding treatments, crested wheatgrass in deep-furrows in coppice soil had the highest emergence. Highest emergence of all species was in deep-furrows but this treatment was not significantly better than the standard drill except with crested wheatgrass in the coppice soil. Emergence in the broadcast-simulated cow trampling treatment was significantly lower than either drill treatment but was significantly higher than the broadcast-no simulated cow trampling treatment. The latter treatment failed or nearly failed for all species in both soils.

At Upper Colly Creek, significantly more seedlings emerged in the coppice than in the interspace soil (Table 6). Emergence of crested wheatgrass was lower than squirreltail in the coppice soil and higher than squirreltail in the interspace, although not significantly. Emergence of both these species was significantly higher than Thurber needlegrass in the coppice soil. Thurber needlegrass emergence was higher in the interspace than squirreltail but lower than crested wheatgrass.

Under the various seeding treatments, crested wheatgrass in deep furrows in

coppice soil had the highest emergence. For all species, differences among standard-drill, deep-furrow drill or broadcast-simulated cow trampling were not significant. Broadcast-no simulated cow trampling emergence was significantly lower than the other three treatments. Highest emergence in interspace soil was by Thurber needlegrass under broadcast-simulated cow trampling.

At Panther Canyon, significantly more seedlings emerged in the coppice than in the interspace soil (Table 7). In coppice soil, emergence of crested wheatgrass was higher than squirreltail, and squirreltail was higher than Thurber needlegrass. The same relationship existed in interspace soil. Squirreltail and Thurber needlegrass emergence in coppice soil was not significantly different from the interspace. No significant difference existed among species within each soil.

Highest emergence was by crested wheatgrass in deep-furrows in coppice soil. For all species, emergence was highest with broadcast-simulated cow trampling but this treatment was not significantly higher than the deep-furrow drill treatment. Standard drill was significantly lower than the broadcast-simulated cow trampling and deep-furrow drill, but significantly higher than broadcast-no simulated cow trampling. In the interspace soil, broadcast-simulated cow trampling gave the highest emergence.

At Paradise Valley, significantly more seedlings emerged in the coppice than in the interspace (Table 8.). Emergence of crested wheatgrass was not significantly higher than squirreltail, but emergence for squirreltail was significantly higher than for Thruber needlegrass. Emergence of Thurber needlegrass was similar in coppice and interspace soils.

Seedling emergence in the standard-drill treatment was significantly highest. The deep-furrow drill treatment gave significantly greater emergence than the broadcast-simulated cow trampling treatment, and broadcast-no simulated cow trampling was significantly lowest and essentially failed. In the standard

coppice soil had the highest emergence. For all species, differences among standard-drill, deep-furrow drill or broadcast-simulated cow trampling were not significant. Broadcast-no simulated cow trampling emergence was significantly lower than the other three treatments. Highest emergence in interspace soil was by Thurber needlegrass under broadcast-simulated cow trampling

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At Paradise Valley, significantly more seedlings emerged in the coppice than in the interspace (Table 8.). Emergence of crested wheatgrass was not significantly higher than squirreltail, but emergence for squirreltail was significantly higher than for Thurber needlegrass. Emergence of Thurber needlegrass was similar in coppice and interspace soils.

Seedling emergence in the standard-drill treatment was significantly highest. The deep-furrow drill treatment gave significantly greater emergence than the broadcast-simulated cow trampling treatment, and broadcast-no simulated cow trampling was significantly lowest and essentially failed. In the standard

drill treatment, emergence of crested wheatgrass and squirreltail was similar in the coppice and interspace soils. The same relationship existed in both broadcast treatments for all species and in deep-furrows.

Fourwing Saltbush Emergence

Fourwing saltbush failed or almost failed when broadcast seeded with no simulated cow trampling at all sites (Table 9.). Highest emergence was at Lower Coils Creek in the drill treatments. This was followed closely by the drill treatments in unplowed soil at Upper Coils Creek, and by the drill treatments at Panther Canyon in plowed soil. Essentially all treatments failed at Paradise Valley. The broadcast-simulated cow trampling treatment failed except in the unplowed soil at Upper Coils Creek and in the plowed area at Panther Canyon.

drill treatment, emergence of crested wheatgrass and squirreltail was similar in the gypsiferous and intermediate soils. The same relationship existed in both broadcast treatments for all species and in deep-furrows.

Fourwing Saltbush Emergence

Fourwing saltbush failed or almost failed when broadcast seeded with no simulated cow trampling at all sites (Table 5.). Highest emergence was at Lower Colls Creek in the drill treatments. This was followed closely by the drill treatments in unplowed soil at Upper Colls Creek, and by the drill treatments at Panther Canyon in plowed soil. Essentially all treatments failed at Paradise Valley. The broadcast-simulated cow trampling treatment failed except in the unplowed soil at Upper Colls Creek and in the plowed area of Panther Canyon.

Table 9. Mean distance between fourwing saltbush plants under the various treatments in both unplowed and plowed treatments at the four study sites.

Treatment	Mean distance between plants (meters)			
	Lower Coils Cr.	Upper Coils Cr.	Panther Canyon	Paradise Valley
Unplowed:				
broadcast-no simulated cow trampling	2286.5	571.6	Infinity	Infinity
broadcast-simulated cow trampling	Infinity	33.6	121.2	Infinity
standard drill	1.3	1.2	Infinity	Infinity
deep furrow drill	.9	1.2	Infinity	Infinity
Plowed:				
broadcast-no simulated cow trampling	571.6	Infinity	1143.3	Infinity
broadcast-simulated cow trampling	143.0	Infinity	26.0	Infinity
standard drill	1.5	54.9	1.4	1800
deep furrow drill	1.0	8.4	1.3	900

SOIL STUDIES

METHODS

The visual character, or physiognomy of the soil surfaces at all four seeding sites is created by distinctive patterns of small, homogenous, repetitive areas with clear boundaries. Each of these micro-areas (about 0.1-10 sq. m) has its own distinctive surface physiognomy, seem to occur in a peculiar microtopographic position, and seem to have a distinctive epipedon morphology (i.e., A horizon morphology). If this could be domonstrated, then rapid, visual line transects could be used to assess epipedon morphology at other sites.

Our major study effort was to identify epipedon morphology in shallow pits along transects through the various types of micro-areas at each seeding site. Soil taxa (i.e., soil Family) at each site was established by morphological profile study in at least three backhoe pits. Profile descriptions were made at each site and samples collected for later determination of particle size distribution, organic carbon content, pH, and some SAR values.

RESULTS AND DISCUSSION

Types of Vesicular Soils

Two types of surficial soil horizons had been recognized before the start of the current study: (1) a hard, massive, and vesicular-crusted type in shrub coppice interspaces, and (2) a noncrusted, very slightly hard, very fine subangular blocky surface type in the shrub coppices. Current field studies at our four seeding sites in northern Nevada have defined <u>four</u> possible surficial horizon types. These types have different degrees of crust expression, occur in different proportions on various soils, and can be distinguished by eye from their surface features.

Soil Surface Morphological Types

The four soil surface morphological types are genetically related to

microtopographic position, or micro-landform, and thus are easily identified and named by their microtopographic positions. However, they cannot be securely identified without examining the morphology of the entire soil. Furthermore, tentative subtypes related to vegetative condition and potential, must be identified by soil morphological details. The major types are listed in Table 1 (see Figure 1 for schematic polygon shapes and morphologies and Figure 2 for microtopographic positions):

Table 1. Soil Surface Morphological Types

Soil Surface Morphological Type Number	Name	Microtopographic Position and Micro-landform
I	Coppice	A semi-conical form, the highest microtopographic elevation.
II	Coppice bench	A flattish or gently sloping area next highest to the coppice, and higher than any adjacent intercoppice microplain or playette, if the latter occur.
III	Intercoppice microplain	A gently sloping or flattish area next lower than the coppice bench. (Absent in some situations).
IV	Playette	A slightly depressional area or flat area at the lowest microtopographic elevation and surrounded by coppices, coppice benches, or coppice microplains. (Absent in some situations).

Within the limited variety of Argids represented by our seeding sites, soil morphological differences among the four major soil surface types consist of (1) external polygon physiognomy, and (2) internal soil morphology of the

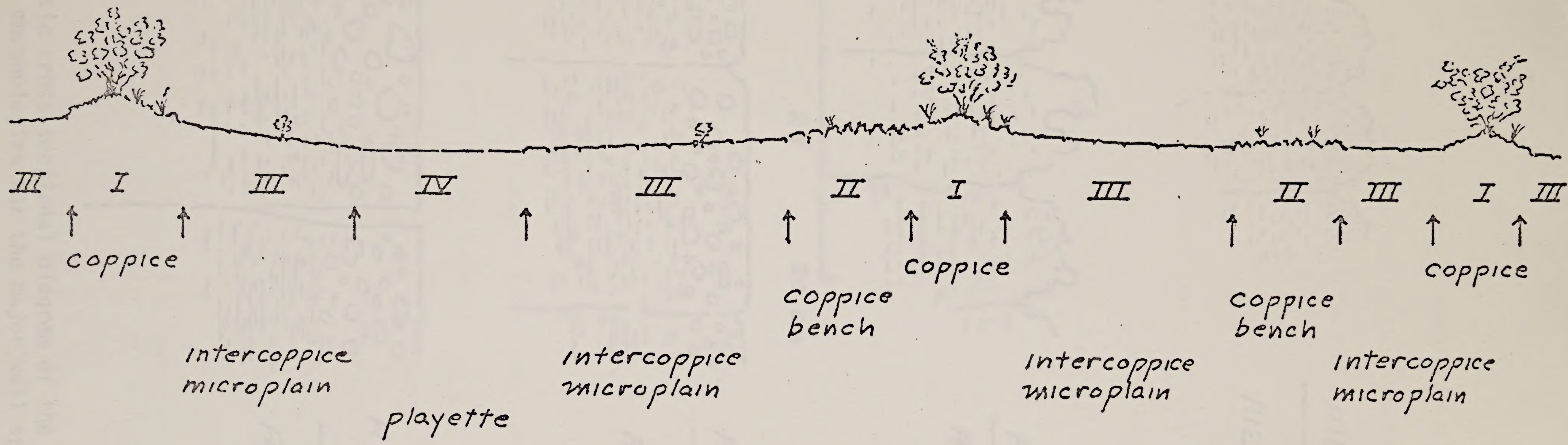

Figure 1. Schematic cross-sectional diagram of the microtopographic positions and forms of the major soil surface morphological types shown along the contour.

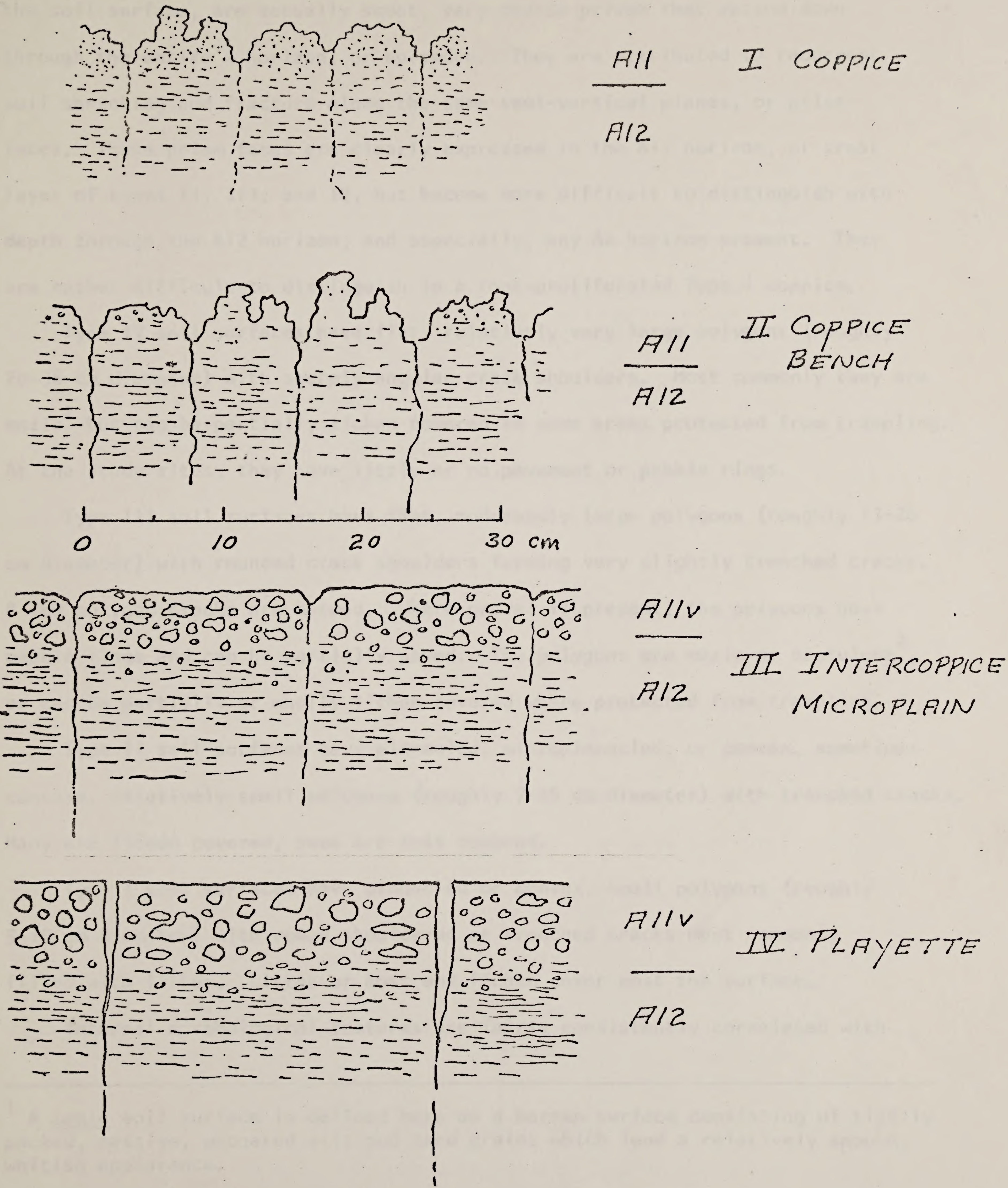

Figure 2. Schematic cross-sectional diagram of the common shrinkage polygon shapes and morphologies for the major soil surface morphology types.

very surface, or A11 horizon. The polygons, named after their outlines at the soil surface, are actually squat, very coarse prisms that extend down through the entire A horizon, or epipedon. They are attributed to recurrent soil shrinking and fracture along the same semi-vertical planes, or prism faces. These prism faces are clearly expressed in the A11 horizon, or crust layer of types II, III, and IV, but become more difficult to distinguish with depth through the A12 horizon, and especially, any A2 horizon present. They are rather difficult to distinguish in a root-proliferated Type I coppice.

Type IV soil surfaces have flat, relatively very large polygons (roughly 20-36 cm diameter) with sharply angular crack shoulders. Most commonly they are mazic[1] but can be partially lichen covered in some areas protected from trampling. At the study sites, they have little or no pavement or pebble rings.

Type III soil surfaces have flat, moderately large polygons (roughly 13-26 cm diameter) with rounded crack shoulders forming very slightly trenched cracks. A few polygon cracks are bermed. Where gravel is present, the polygons have pebble rings and can be partially paved. The polygons are mazic or pustulose[2], or can be partially or wholly lichen covered where protected from trampling.

Type II soil surfaces have pinnacled, micropinnacled, or convex, sometimes concave, relatively small polygons (roughly 7-15 cm diameter) with trenched cracks. Many are lichen covered, some are moss covered.

Type I soil surfaces have pinnacled or convex, small polygons (roughly 5-10 cm diameter) with round shouldered or trenched cracks most commonly filled with litter. Litter or moss and lichen cover most the surface.

Internal morphological features are fairly consistently correlated with

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[1] A mazic soil surface is defined here as a barren surface consisting of tightly packed, massive, uncoated silt and sand grains which lend a relatively smooth, whitish appearance.

[2] A pustulose surface is a mazic surface that is finely pitted and bumpy.

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Type IV soil surfaces have flat, relatively very large polygons (roughly 20-35 cm diameter) with sharply angular crack shoulders. Most commonly they are mazic[1] but can be partially lichen covered in some areas protected from trampling. At the study sites, they have little or no pavement or pebble rings.

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Type I soil surfaces have pinnacled or convex, small polygons (roughly 5-10 cm diameter) with round shouldered or crumbled cracks most commonly filled with litter. Litter or moss and lichen cover most the surface.

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[2] A vermiculose surface is a mazic surface that is finely pitted and lumpy.

external polygon features and microtopographic position. They must be used to confirm visual soil surface morphological identifications, or to decide identity where visible features are intermediate. The most distinctive internal morphological features of the polygons (i.e., squat prisms) occur in the very surface subhorizon, i.e., an A11v or A11 subhorizon.

In soil surface morphological Types III and IV this surficial A11v subhorizon (postscript v indicates vesicular) is a prominent, relatively thick (4-8 cm) crust that is massive and coarsely vesicular (1 mm diameter vesicles dominantly). The A12 subhorizon is distinguished from the A11v subhorizon by the former's platyness. Where recently trampled, the upper 2 cm of the A11v is massive and lacking coarse vesicles, whereas the lower part retains its coarse vesicles. At any particular site, this massive, coarsely vesicular A11v subhorizon is thickest on Type IV surfaces (4-8 cm thick) and thinner on Type III surfaces (1.5-4 cm thick).

Type II soil surfaces and pinnacled Type I soil surfaces most commonly have no coarsely vesicular massive crust; if it occurs on a Type II surface it is 2 cm thick and has suggestions of a weak, medium platyness. The A11 horizon here is distinguished by its fragility (i.e., very slightly hard) whether it is finely platy and subangular blocky, or nonvesicular-massive, or finely vesicular-massive. Delicate dessection can show surficial crust (at least 1-3 mm thick) but it is apt to be overlooked except on Type II surfaces without pinnacles (i.e., convex or concave polygons).

Type I surfaces consistently have a weak to moderate, very fine subangular blocky (1 mm) structured A11 subhorison if covered with litter, lichen, or moss.

Both the barren, undisturbed mineral soil surfaces and crushed A11v subhorizons or Type IV surfaces are lightest in value and lowest in chroma (e.g., 6-7/2-3 dry, 4/2-3 moist, crushed). The undisturbed Type III mineral soil

surfaces commonly are slightly darker than the Type IV and lighter than the Type II. Barren Type II surfaces commonly have slightly higher chroma than Type III, and are noticeably darker and higher chroma than Type IV surfaces. Type I surfaces have the darkest colored A11 horizons (e.g., 4-5/1-2 dry, 3-4/1-2 moist, crushed).

Size and Shape of Areas of Soil Surface Morphological Types

Type I coppices almost always support big sagebrush at the study sites and are somewhat larger than the shrub canopy. They are semicircular (0.2-1.0 m diameter) under single shrubs, or form lobate or beaded areas up to several meters long where shrubs are closely spaced.

Type II coppice benches most commonly form 0.3-1.5 m wide, discontinuous, lobate margins alongside coppices. In some cases they are irregularly lobate, 0.5-3 m wide areas without an adjacent coppice, but fragments of dead big sagebrush occur within most such areas. At one seeding site (Panther Canyon) the Type II surface forms an almost continuous matrix area for closely spaced coppices, i.e., there is very little Type III or IV surface. During heavy rains or snowmelt periods, water is not seen standing on, and seldom seen running across Type I or II surfaces.

Type III intercoppice microplains are probably the most extensive surface type for most Aridisols. They form continuous, gentle, roughly 0.2-5 m wide slopes between and around coppices and coppice benches; frequently they are almost flat for an 0.3-2 m reach, forming indistinct steps similar to playettes. During heavy rainstorms and snowmelt, water runs over, and stands briefly on Type III surfaces. Where surfaces are flattish, thin scums of ice form at night during major snowmelts.

Type IV playettes occur as semicircular or elongated flats or very shallow depressions 0.5-5 m wide. Water stands on them longest after moderate rainstorms or snowmelt periods. Ice sheets up to several centimeters thick regularly form

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Vegetation Patterns

At the seeding sites studied, the Type I coppices regularly support big sagebrush; occasionally the shrub is dead but the coppice is still intact. Bunchgrass might or might not occur under or to the side of the shrubs, depending on range condition. The interior of the coppice is commonly at least partially litter covered, otherwise mostly moss and lichen covered. Coppice margins show more bare soil and prominent pinnacling with Sandberg bluegrass on top of some pinnacles.

The Type II surfaces are poorly vegetated, except at the Panther Canyon site. Sandberg bluegrass bunches are pedestaled (i.e., on a pinnacle) and occur near a polygon trenched crack, if not in it. Cheatgrass grows out of the trenched cracks and commonly covers the small polygons with litter. Seedling big sagebrush plants also occur in the trenched cracks, as do a few phlox plants. At some sites very well protected from trampling, lichen can cover the entire Type II surface.

The Type III surfaces are mostly barren. Phlox and seedling big sagebrush grow from the slightly trenched or rounded cracks and a very few Sandberg bluegrass or squirreltail bunches grow beside cracks at some sites. At some sites very well protected from trampling, lichen can cover the entire Type III surface.

Type IV surfaces are almost invariably barren except for partial lichen cover around polygon margins at some sites very well protected from trampling.

Soil Surface Morphological Type Genesis

From site to site on different kinds of soils, the proportions of soil surface morphological types (i.e., the proportion of massive vesicular crusted soil) and the degree of crust expression for a surface type -- particularly

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Soil Surface Morphological Type Genesis

From site to site on different kinds of soils, the proportions of soil surface morphological types (i.e., the proportion of massive vesicular crusted soil) and the degree of their expression for a surface type -- particularly

Type III surface -- apparently varies with microtopography, kind of soil materials, and probably kind of profile and climate. We have substantial field evidence from which genetic mechanism and sequence can be postulated.

Genesis of Types IV and III Soil Surfaces:

Massive vesicular crusting results from recurrent saturation then dessication of readily slaked silty soil material. For a particular soil site, surficial saturation depends on water infiltrating more rapidly than it percolates down and out of the surficial subhorizon. Microtopographic positions that receive runoff in addition to precipitation and pond, or can only slowly dispose of surface runoff (i.e., positions of Type IV playettes and Type III intercoppice microplains) have the highest potential for surficial saturation. We find the thickest massive vesicular crusts in playettes, thinner ones on intercoppice microplains, and little or no such crusting on coppice benches or coppice.

Given rapid enough water addition to pond or sheet-flood, soil hydraulic conductivity determines the rate and depth of soil saturation. Slaking very fine sandy loams and silt loams probably have such a critically low hydraulic conductivity, in addition to those capillary properties necessary for vesicle formation and perhaps platy structure formation. (The exceptional paucity of Type III and IV surfaces on the Panther Canyon silt loam soils might be due to a particularly pervious and thick A horizon.)

Two other morphological features probably abet low A horizon hydraulic conductivity to cause surficial saturation. Water percolating by unsaturated flow is markedly retarded when it passes from a finely porous layer to a more coarsely porous layer. The prominent fine platy structure of the A12 subhorizons, in the soils we studied, interjects coarse horizontal pores below the surficial A11 subhorizon and might tip the scales for sufficiently low water tension in the A11 horizon to cause vesicular crusting.

Water penetration is also retarded by underlying, slowly pervious argillic or natric horizons. During major storms and snowmelt, enough water is added to many Aridisols -- particularly in the playette position -- to fill the A horizon if it cannot percolate through the argillic or natric horizon. After storms on dry soils, some Type IV playette surfaces are temporarily and shallowly ponded and saturated down to, and a centimeter or so past, a shallow (10-15 cm) abrupt textural boundary to a clayey argillic or natric horizon. Adjacent Type III, II, and I surfaces on thicker A horizons are more deeply wetted and neither saturated nor ponded. In some soil landscapes or eastern Washington, Oregon, and southern Idaho, massive vesicular soil surfaces are coincident with small spots of Natrixerolls or Natrargids in a matrix of Haploxerolls. In southern Idaho, Type IV playette surfaces are coincident with spots of thinner A horizons on continuous Nardurargids. At our study sites, shallow argillic or natric horizons might determine location of some, but probably not all Type IV playette surfaces.

Genesis of Types I and II Soil Surfaces:

Type I coppice surfaces are the apparent result of accumulation of windblown soil material at the base of a shrub that sprouted in a Type II or III surface. Concurrent incorporation of litter and root residues leads to higher humus contents and formation of moderate very fine subangular blocky structure. Primary evidence for coppice dune aeolian accumulation is continuity of the relatively light colored A11v subhorizon of contiguous Type III surfaces horizontally under the slightly higher, darked colored, semiconical A11 horizon of a coppice. The coppice A11 horizon commonly is slightly sandier than an adjacent Type III A11 horizon, and than the buried, apparent lateral extension of adjacent A11v subhorizon. Where buried under a coppice, this former soil surface horizon apparently acquires the prominent compound fine platy and very fine subangular blocky structure that is characteristic of the continuous A12 horizon present under all four surface types. Thus, under a coppice the A12 appears slightly

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thicker with a slightly lighter grey color in its upper 4-6 cm (i.e., the buried former surficial horizon) than away from the coppice. Occurrence of big sagebrush seedlings in polygon cracks of Type II or III surfaces, without coppice dunes, somewhat larger bushes with small coppice dures, and large old bushes with relatively high coppice dunes are accessory evidence of accumulation.

The margins of Type I coppices are prominently pinnacled where not litter covered; some are barren and appear eroded as well as pinnacled. Where bushes have died recently, litter cover is absent and the yet semiconical coppice dune is strongly pinnacled, frequently mostly bare, and gives the impression of being eroded. Where only a few trampled down, centripedally strewn fragments of a dead sagebrush occur on a Type II pinnacled surface, there is no longer a semiconical peak, or dune coppice form at the site of the shrub crown. This apparent sequence suggests Type II surfaces are the flattened and pinnacled remnants of former coppice dunes.

Trampling Effects

Cow trampling, particularly along traffic paths between shrub coppices, disrupts the A11 subhorizons of the various surface types. It is least disruptive on Type I coppices, since the animals seldom step into a shrub coppice, and on the Type IV playettes, since surficial mixing little alters the already very inhospitable plant environment.

Trampling Type II coppice benches and Type III intercoppice microplains -- both located in the major traffic routes -- destroys trenched cracks, A11 subhorizon structure, surface roughness (pinnacles), and stabilizing lichen and moss cover. The powdered soil material is liable to wind or water erosion. When it rewets, it initially slakes to a slightly hard, or hard, massive microporous crust that our greenhouse trials suggest is a very poor seed bed. Type II A11 material doesn't seem to slake to as hard a crust, and seems to develop platyness

thicker with a slightly lighter grey color in its upper 4cm (i.e., the buried former vesicular horizon) than many Type III surfaces. Occurrence of big sagebrush seedlings in polygon cracks of Type II or III surfaces, without coppice dunes, somewhat larger bushes with small coppice dunes, and large old bushes with relatively high coppice dunes are secondary evidence of succession.

The margins of Type I coppices are prominently pinnacled where not litter covered; some are barren and appear eroded as well as pinnacled. Where shrubs have died recently, litter cover is absent and the wet semiconical coppice dune is strongly pinnacled, frequently mostly bare, and gives the impression of being eroded. Where only a few trampled down, decomposing straw fragments of a dead sagebrush occur on a Type II pinnacled surface, there is no longer a semiconical peak, or dune coppice form at the site of the shrub crown. This apparent sequence suggests Type II surfaces are the flattened and pinnacled remnants of former coppice dunes.

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Trampling Type II coppice benches and Type III interspace or microplains -- both located in the major traffic routes -- destroys trenched cracks, A11 subhorizon structure, surface roughness (pinnacles), and stabilizing lichen and moss cover. The powdered soil material is liable to wind or water erosion. When it rewets, it initially slakes to a slightly hard, or hard, massive microporous crust that our greenhouse trials suggest is a very poor seed bed. Type II A11 material already seems to slake to as hard a crust, and seems to develop platyness

more rapidly than Type III material on repeated wetting-drying. Field observations suggest the degree of crusting and rate of surface morphology reformation depends both on the original type soil surface trampled, and on the texture and humus content of the A11 subhorizon soil material -- perhaps the entire epipedon and profile -- at any particular site (i.e., kind of soil at the soil series or phase level).

Morphological Sequence of Surface Reformation

Cow trampling disrupts and powders the A11 horizons of all surface types. Each appears to reform in time if its microtopographic postition hasn't been obliterated. In all cases, the powdered A11 subhorizon appears to slake to a massive, nonvesicular crust with relatively large, flat, incomplete, angular-shouldered polygons on first or first several wettings. After trampling, Type IV surface material reforms its coarse vesicles, and is then as it was. Type III surface material appears to regain coarse vesicularity and rounded or slightly trenched cracks, and is recompleted. Type II material appears to first form rounded cracks and marginal micropinnacles on the polygons, then trenched cracks and full pinnacles. Its initially massive nonvesicular surface becomes platy and friable. Where trampling destroys the shrubs on Type I coppices, they probably convert to Type II surfaces.

OFF ROAD VEHICLE EFFECTS

METHODS

Summer treatments were made at the Crystal Springs and Las Vegas study sites. Treatments at Crystal Springs were multiple truck (20) pass, multiple motorcycle (50) pass, and control. Treatments at Las Vegas were single truck pass, single motorcycle pass, multiple truck (20) pass, multiple motorcycle (50) pass, and control. Simulated precipitation was applied to a 1422 cm^2 runoff plot at the rate of 3.375 cm/hr for 30 minutes. Infiltration was measured every 5 minutes; total sediment was collected after 30 minutes. Plots were covered with plastic and the soil surface horizon allowed to dry and reform. After reformation, simulated precipitation was applied again on the same plots at the same rate as before and the same data were collected.

RESULTS AND DISCUSSION

Infiltration rate

Five minute and terminal (30 min.) infiltration rates were calculated (Table 1). Infiltration did not differ between the two study locations. Infiltration rates were lower on the second infiltration run (ORV disturbance followed by reformation of the soil surface crust) than on the first run. The reduction in infiltration in the second run was small on coppice soils but very great on the interspace soil (Table 2). At Las Vegas, infiltration on the single-motorcycle and single-truck treatments were not different from the control. At both sites, infiltration rates on the multiple-motorcycle and multiple-truck treatments were lower than on the control. At both locations and with all treatments, infiltration was less on the interspace soil than on the coppice soil. At Crystal Springs, infiltration rate on both coppice and interspace soils was less after disturbance and reformation. At Las Vegas, infiltration on the interspace soil only was reduced by reformation. Disturbance by the

Table 1. Mean terminal infiltration rate (cm/hr) in response to imposed variables.[1/]

Variable	Terminal Infiltration
Study Site	
Crystal Springs	1.73 a
Las Vegas	1.90 a
Run	
First	2.17 a
Second	1.46 b
ORV Treatment	
multiple motorcycle	1.52 a
multiple truck	1.60 a
control	2.32 b
Soil	
Interspace	0.94 a
Coppice	2.68 b

1/ Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test.

Table 2. Mean terminal infiltration rate (cm/hr) as influenced by run and soil.[1/]

Run and Soil	Terminal Infiltration
First	
Interspace	1.37 b
Coppice	3.00 d
Second	
Interspace	0.52 a
Coppice	2.40 c

1/ Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test.

multiple-motorcycle treatment at Las Vegas gave the greatest reduction in infiltration between the coppice and interspace soils on the first and second runs (Fig. 1). The multiple-truck treatment did not result in as large a reduction in infiltration in the first run (Fig. 2). These data appear to support results from 1974 that indicated an increase in infiltration caused by the multiple truck disturbance of interspace soil. However, after crust reformation the multiple truck treatment caused the greatest reduction in infiltration between the first and second runs on the coppice soil (Table 3). (Fig. 3). Perhaps the interspace soil after severe disturbance, wetting, and drying forms a more inpermeable crust than before. In addition, Figure 3 suggests that just wetting and drying without disturbance, can change the infiltration characteristics of interspace soil. The high infiltration capacity of the coppice soil was reduced by the multiple-truck treatment on both the first and second runs. The infiltration capacity of both coppice and interspace soils at Crystal Springs was reduced by both multiple ORV treatments. At Las Vegas, infiltration on coppice soil was reduced by multiple ORV treatments, while infiltration on the interspace soil was reduced by the multiple-motorcycle treatment only.

Sediment Production

Sediment production in response to imposed variables was determined by amount of suspended material in runoff samples (Table 4). Sedimentation was greater at the Las Vegas site than at Crystal Springs. At Las Vegas, the single motorcycle and single truck treatments were similar to the control. However, at both locations, the multiple ORV treatments produced more sediment than did the control. Sediment production was greatest on the multiple truck treatment after crust reformation. Sediment produced from the interspace soil was ten times greater than from the coppice soil. At both locations, sediment from the

multiple-motorcycle treatment at Las Vegas gave the greatest reduction in infiltration between the coppice and interspace soils on the first and second runs (Fig. 1). The multiple-truck treatment did not result in as large a reduction in infiltration in the first run (Fig. 2). These data appear to support results from 1976 that indicated an increase in infiltration caused by the multiple truck disturbance of interspace soil. However, after crust reformation the multiple truck treatment caused the greatest reduction in infiltration between the first and second runs on the coppice soil (Table 3), (Fig. 3). Perhaps the interspace soil after severe disturbance, wetting, and drying forms a more impermeable crust than before. In addition, Figure 3 suggests that just wetting and drying without disturbance, can change the infiltration characteristics of interspace soil. The high infiltration capacity of the coppice soil was reduced by the multiple-truck treatment on both the first and second runs. The infiltration capacity of both coppice and interspace soils at Crystal Springs was reduced by both multiple ORV treatments. At Las Vegas, infiltration on coppice soil was reduced by multiple ORV treatments, while infiltration on the interspace soil was reduced by the multiple-motorcycle treatment only.

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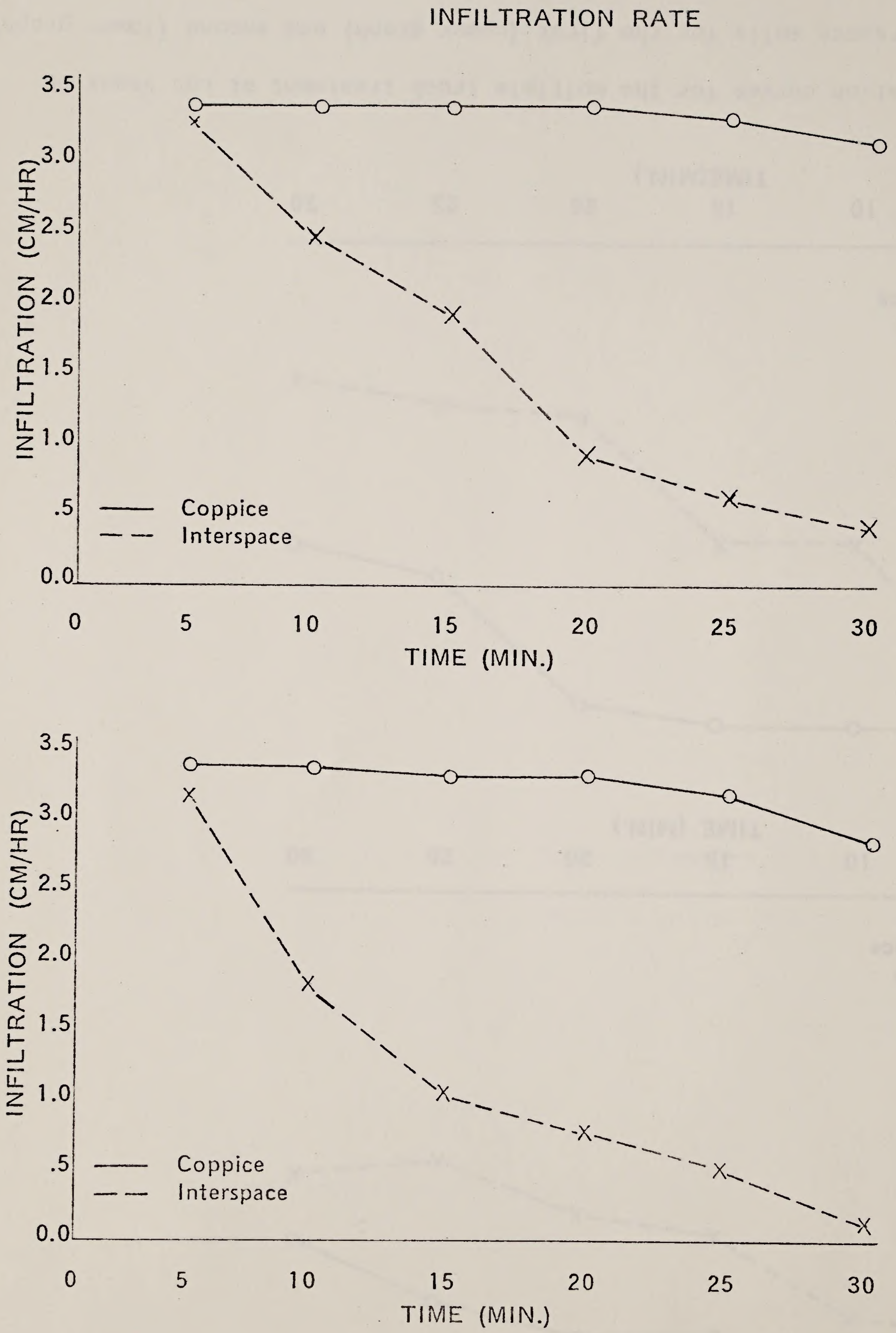

Figure 1. Infiltration curves for the multiple motorcycle treatment at Las Vegas on coppice and interspace soils for the first (upper graph) and second (lower graph) runs.

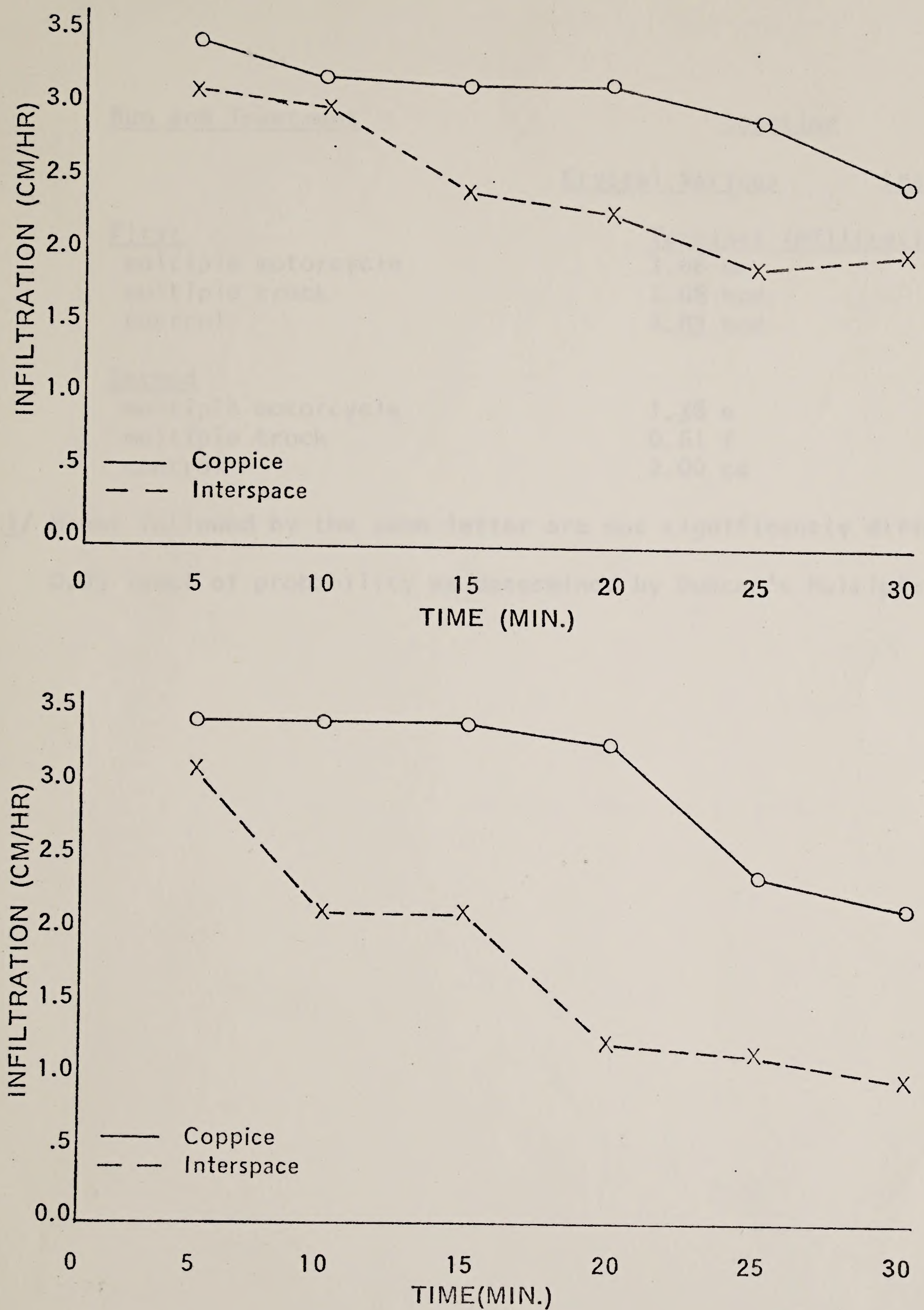

Figure 2. Infiltration curves for the multiple truck treatment at Las Vegas on coppice and interspace soils for the first (upper graph) and second (lower graph) runs.

Table 3. Mean terminal infiltration rate (cm/hr) at two sites as influenced by run and ORV treatment.[1/]

Run and Treatment	Crystal Springs	Las Vegas
	Terminal Infiltration	
First		
multiple motorcycle	1.46 de	1.78 cde
multiple truck	2.08 bcd	2.18 bc
control	2.83 bcd	2.65 ab
Second		
multiple motorcycle	1.38 e	1.45 de
multiple truck	0.61 f	1.54 de
control	2.00 cd	1.78 cde

1/ Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test.

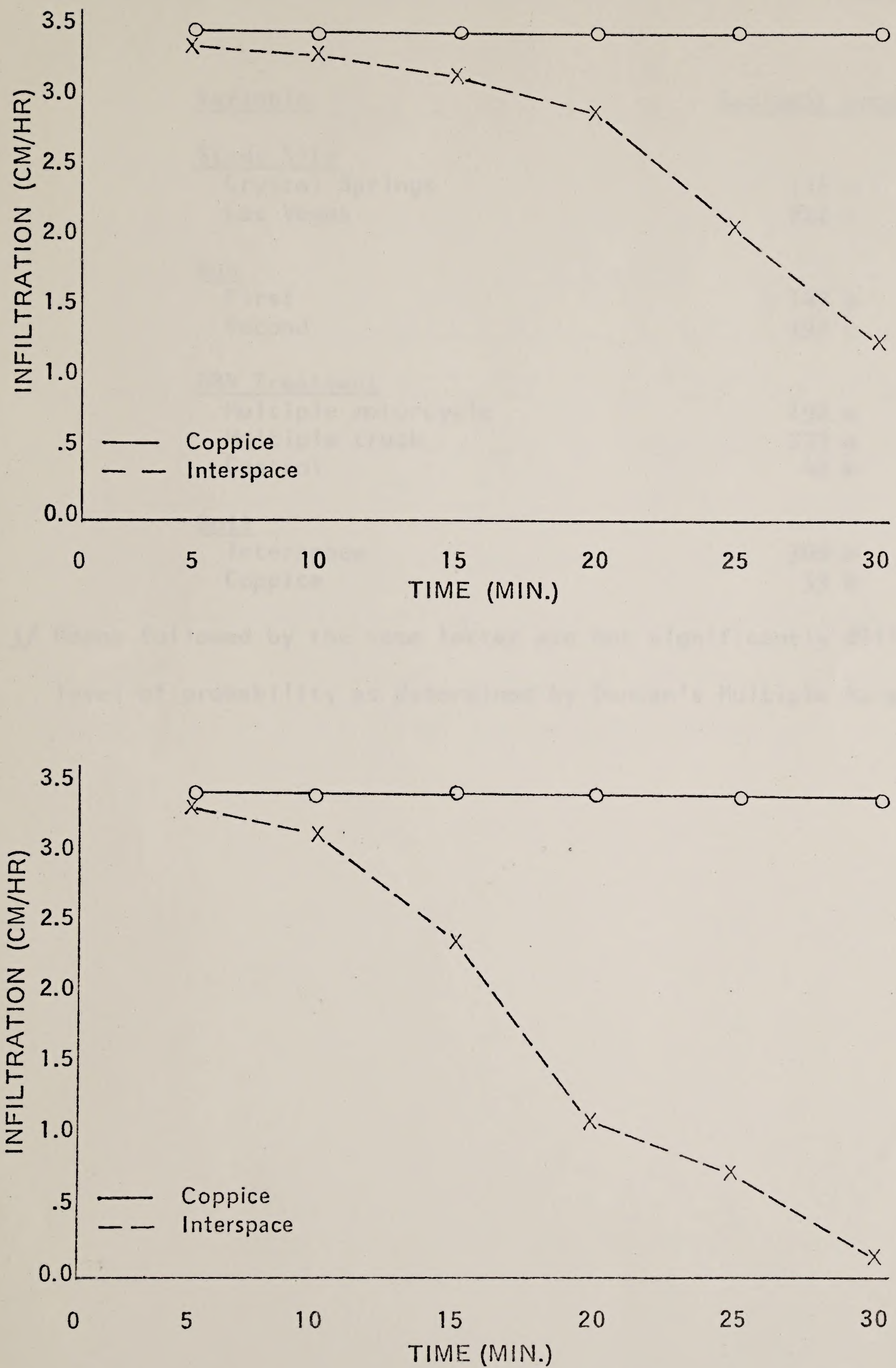

Figure 3. Infiltration curves for the control treatment at Las Vegas on coppice and interspace soils for the first (upper graph) and second (lower graph) runs.

Table 4. Sediment production (kg/ha) in response to imposed variables.[1/]

Variable	Sediment production
Study Site	
Crystal Springs	116 a
Las Vegas	222 b
Run	
First	147 a
Second	192 a
ORV Treatment	
Multiple motorcycle	192 a
Multiple truck	273 a
Control	42 b
Soil	
Interspace	306 a
Coppice	33 b

1/ Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test.

control was similar in the coppice and interspace soils. However, at both locations the multiple ORV treatments resulted in more sediment from the interspace than from the coppice (Table 5).

These results suggest the following tentative conclusions: 1) Although runoff between sites was similar, more suspended sediments were carried in the runoff water at the Las Vegas site. 2) In general, although more water ran off after crust reformation, the amount of sediment in the water was similar between runs. 3) Both multiple ORV treatments caused more runoff with more sediment than did the control. 4) The amount of both runoff and sediment were much greater from the vesicular interspace soil than from the coppice. 5) The greatest sediment production resulted from multiple ORV treatments on the interspace soil after crust reformation. These tentative conclusions suggest that runoff and sediment production will be greater: 1) with disturbances, 2) the greater the proportion of surface with a vesicular horizon in the interspace, and 3) particularly after disturbed interspace vesicular surface soil reforms after wetting and drying.

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Table 5. Mean sediment production (kg/ha) in response to location, ORV treatment, and soil.[1/]

	Location	
	Crystal Springs	Las Vegas
ORV Treatment and soil	Sediment Production	
Multiple motorcycle - interspace	257 b	494 a
Multiple motorcycle - coppice	12 c	6 c
Multiple truck - interspace	272 b	649 a
Multiple truck - coppice	107 bc	64 c
Control - interspace	41 c	122 bc
Control - coppice	8 c	0 c

1/ Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test.